Tennessee Science Curriculum Framework

Chemistry II

Course Description

Chemistry II is a laboratory science course that builds on topics taught in Chemistry I. This course investigates chemical bonding and how the kinetic molecular theory and by intermolecular forces explain the physical and chemical characteristics of matter. Additional aspects of chemical reactions including limiting reactants, percent yield, equilibrium, reaction rates, and thermochemistry are considered. Students explore chemistry concepts through an inquiry approach.

Chemistry II students will study:

- Inquiry
- Technology and Engineering
- Structure of Matter
- States of Matter
- Reactions

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3222.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3222.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3222.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3222.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3222.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3222.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

✓**3222.Inq.1** Trace the historical development of a scientific principle or theory.
✓**3222.Inq.2** Identify an answerable question and formulate a hypothesis to guide a scientific investigation.
✓**3222.Inq.3** Design a simple experiment including appropriate controls.
✓**3222.Inq.4** Perform and understand laboratory procedures directed at testing hypothesis.
✓**3222.Inq.5** Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
✓**3222.Inq.6** Correctly read a thermometer, balance, metric ruler, graduated cylinder, pipette, and burette.
✓**3222.Inq.7** Record observations and/or data using correct scientific units and significant figures.
✓**3222.Inq.8** Export data into the appropriate form of data presentation (e.g., equation, table, graph, or diagram).
✓**3222.Inq.9** Translate data into the correct units and dimension using conversion factors and scientific notation.
✓**3222.Inq.10** Analyze information in a table, graph or diagram (e.g., compute the mean of a series of values or determine the slope of a line).
✓**3222.Inq.11** If accepted values are known, calculate the percent error for an experiment.
✓**3222.Inq.12** Determine the accuracy and precision of experimental results.
✓**3222.Inq.13** Analyze experimental results and identify possible sources of bias or experimental error.
✓**3222.Inq.14** Recognize, analyze, and evaluate alternative explanations for the same set of observations.
✓**3222.Inq.15** Design a model based on the correct hypothesis that can be used for further investigation.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

CLE 3222.T/E.1 Explore the impact of technology on social, political, and economic systems.
CLE 3222.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
CLE 3222.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.

CLE 3222.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3222.T/E.1** Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- ✓**3222.T/E.2** Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓**3222.T/E.3** Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- ✓**3222.T/E.4** Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓**3222.T/E.5** Evaluate the overall benefit to cost ratio of a new technology.
- ✓**3222.T/E.6** Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓**3222.T/E.7** Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Embedded Mathematics

Conceptual Strand

Science applies mathematics to investigate questions, solve problems, and communicate findings.

Guiding Question

What mathematical skills and understandings are needed to successfully investigate chemistry?

Course Level Expectations

CLE 3222.Math.1 Understand the mathematical principles associated with the science of chemistry.

CLE 3222.Math.2 Utilize appropriate mathematical equations and processes to solve chemistry problems.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3222.Math.1** Use a variety of appropriate notations (e.g., exponential, functional, square root).
- ✓**3222.Math.2** Select and apply appropriate methods for computing with real numbers and evaluate the reasonableness of the results.
- ✓**3222.Math.3** Apply algebraic properties, formulas, and relationships to perform operations on real-world problems such as: solving for density, determining the concentration of a solution in a variety of units (ppm, ppb, molarity, molality, and percent composition), calculating heats of reactions and phase changes, and manipulating gas law equations.

- ✓**3222.Math.4** Interpret rates of change from graphical and numerical data (e.g., phase diagrams, solubility graphs, colligative properties, nuclear decay or half-life).
- ✓**3222.Math.5** Analyze graphs to describe the behavior of functions (e.g., concentration of a solution, phase diagrams, solubility graphs, colligative properties, nuclear decay half-life).
- ✓**3222.Math.6** Model real-world phenomena using functions and graphs.
- ✓**3222.Math.7** Apply and interpret algebraic properties in symbolic manipulation (e.g., density, concentration of a solution, chemical equations, effect of volume, temperature or pressure on behavior of a gas, percent composition of elements in a compound, molar mass, number of moles, and molar volume, amount of products or reactants given mole, molarity, volume at STP or mass amounts, heat loss or gain using mass, temperature change and specific heat, and half-life of an isotope)
- ✓**3222.Math.8** Apply and communicate measurement units, concepts and relationships in algebraic problem-solving situations.
- ✓**3222.Math.9** Select appropriate units, scales, and measurement tools for problem situations involving proportional reasoning and dimensional analysis.
- ✓**3222.Math.10** Choose, construct, and analyze appropriate graphical representations for a data set.
- ✓**3222.Math.11** Identify and solve different types of stoichiometry problems (e.g., volume at STP to mass, moles to mass, molarity).
- ✓**3222.Math.12** Calculate the amount of product expected in a lab experience and determine percent yield.
- ✓**3222.Math.13** Convert among the quantities of a substance: mass, number of moles, number of particles, molar volume at STP.

State Performance Indicators

- **SPI 3222.Math.1** Use real numbers to represent real-world applications (e.g., slope, rate of change, probability, and proportionality).
- **SPI 3222.Math.2** Perform operations on algebraic expressions and informally justify the procedures chosen.
- **SPI 3222.Math.3** Interpret graphs that depict real-world phenomena.
- **SPI 3222.Math.4** Apply measurement unit relationships including Avogadro's number, molarity, molality, volume, and mass to balance chemical equations.
- **SPI 3222.Math.5** Use concepts of mass, length, area, and volume to estimate and solve real-world problems.

Standard 1 – Structure of Matter

Conceptual Strand 1

Atomic theory is the foundation for understanding the interactions and changes in matter.

Guiding Question 1

How does the structure of matter determine its chemical and physical properties?

Course Level Expectations

CLE 3222.1.1 Explain and illustrate the arrangement of electrons surrounding an atom.

CLE 3222.1.2 Relate the arrangement of electrons surrounding an atom with observed periodic trends.

CLE 3222.1.3 Describe the structure, shape, and characteristics of polyatomic ions, ionic and molecular compounds.

Checks for Understanding (Formative/Summative Assessment)

✓**3222.1.1** Calculate the wavelength, frequency and energy of a photon of electromagnetic radiation.

✓**3222.1.2** Determine the energy level transition of an electron for a particular wavelength of electromagnetic radiation.

✓**3222.1.3** Correlate lines in an emission spectra of the hydrogen atom to their respective energy-level transitions.

✓**3222.1.4** Describe the arrangement of electrons in any atom using orbital diagrams, electron configuration notation, and Lewis structures.

✓**3222.1.5** Explain the periodic trends of the main group elements including atomic and ionic radii, ionization energies, and electron affinities.

✓**3222.1.6** Explain the role of electron shielding and effective nuclear charge in determining the atomic and ionic radii, ionization energy, and electron affinities of an atom or ion.

✓**3222.1.7** Explain why the principle quantum number of the valence electrons correlates with the atomic and ionic radii, ionization energy, and electron affinities of an atom or ion.

✓**3222.1.8** Use Lewis structures to illustrate the structure, shape, and characteristics of polyatomic ions, ionic and molecular compounds.

✓**3222.1.9** Illustrate the shape of molecular compounds using VSEPR theory.

✓**3222.1.10** Determine the polarity of a molecular compound by examining its bond dipoles and shape.

✓**3222.1.11** Determine if a compound or polyatomic ion forms resonance structures using Lewis structures and formal charge analysis.

✓**.3222.1.12** Explain the formation of hybridized bond orbitals in molecular compounds using VSEPR and valence bond theory.

✓**3222.1.13** Illustrate how sigma and pi bonds form between atoms in a molecular compound.

✓**3222.1.14** Draw the basic functional groups found in organic molecules.

✓**3222.1.15** Draw the structural formulas of simple organic molecules.

Standard 2 – States of Matter

Conceptual Strand 2

Kinetic-molecular theory and intermolecular forces are the basis for solid, liquid, gas, and solution phenomena.

Guiding Question 2

How does the interaction between ions and molecules determine the physical state and characteristics of matter?

Course Level Expectations

CLE 3222.1 Explain the kinetic-molecular theory.
CLE 3222.2 Determine the intermolecular forces that exist between ions and molecules.
CLE 3222.3 Explain how the physical characteristics of matter are governed by kinetic molecular theory and intermolecular forces.

Checks for Understanding (Formative/Summative Assessment)

✓**3222.2.1** Correlate the kinetic-molecular theory with the motion of particles within a substance.
✓**3222.2.2** Explain the effect of heat on temperature in terms of the motion of the particles within the substance.
✓**3222.2.3** Explain how the motion of gas molecules affects the pressure.
✓**3222.2.4** Explain the effects of temperature changes on the pressure of a gas.
✓**3222.2.5** Explain the effects of pressure changes on the volume of a gas.
✓**3222.2.6** Solve complex combined and ideal gas law problems to quantitatively explain the behavior of gases.
✓**3222.2.7** Determine the rates of effusion of gas molecules using Graham's Law of Effusion.
✓**3222.2.8** Explain conditions where real gases deviate from ideal behavior.
✓**3222.2.9** Determine the types of intermolecular interactions that occur in a pure substance or between the components of a mixture.
✓**3222.2.10** Compare the strengths of intermolecular forces between ions, molecules, and ion-molecule mixtures.
✓**3222.2.11** Correlate the strength of the intermolecular force with the viscosity, surface tension and physical state of the substance at a given temperature.
✓**3222.2.12** Explain the role of intermolecular forces in determining the vapor pressure, volatility and boiling point of a substance.
✓**3222.2.13** Use a phase diagram of a substance to identify its triple-point, critical temperature, and pressure.
✓**3222.2.14** Apply a phase diagram to interpret the effects of temperature and pressure on the phase of the substance.
✓**3222.2.15** Calculate the effect of solute concentration on vapor pressure using Raoult's Law.

✓**3222.2.16** Calculate the freezing point depression and boiling point elevation of a solution based on appropriate constants, quantities of solute and solvent, and type of solute.

✓**3222.2.17** Use the freezing or boiling points of the solution, appropriate constants, and the amount solute or solvent to calculate the molar mass of a solute.

Standard 3 – Reactions

Conceptual Strand 3

Chemical reactions can be investigated and described through their stoichiometric, kinetic, equilibrium, and thermodynamic characteristics.

Guiding Question 3

How can the stoichiometric, kinetic, equilibrium, and thermodynamic characteristics of a chemical reaction lead to a further understanding of reaction process?

Course Level Expectations

CLE 3222.3.1 Use the reactants of a chemical reaction to predict the products.

CLE 3222.3.2 Fully analyze the quantitative aspects of a chemical reaction in terms of the amounts of products and reactants.

CLE 3222.3.3 Analyze the kinetics of a chemical reaction.

CLE 3222.3.4 Describe parameters of chemical equilibria.

CLE 3222.3.5 Explain the thermodynamics of a chemical reaction.

Checks for Understanding (Formative/Summative Assessment)

✓**3222.3.1** Apply an activity series to predict products and write net ionic reactions that identify spectator ions in a single-replacement reaction.

✓**3222.3.2** Use a solubility chart to predict products and write net ionic reactions that identify spectator ions in a double-replacement reaction given.

✓**3222.3.3** Identify the oxidation states of ions in an oxidation-reduction reaction.

✓**3222.3.4** Balance an oxidation-reduction reaction performed in neutral, acidic or basic environment.

✓**3222.3.5** Use reduction potentials to determine the anode and cathode reactions in an electrochemical cell, and calculate the standard reduction potential of the cell.

✓**3222.3.6** Apply reduction potentials to identify oxidizing and reducing agents and determine their relative strengths.

✓**3222.3.7** Calculate the number of moles, mass, number of ions, atoms, and molecules, volume, and pressure of reactants and products in a chemical reaction based on appropriate constants and quantitative information about reaction components.

- ✓**3222.3.8** Calculate the amount of remaining reactants and product in a situation where one of the reactants is limiting.
- ✓**3222.3.9** Calculate the rate of a chemical reaction based on the elapsed time and amounts of remaining reactant or product.
- ✓**3222.3.10** Use the rate law and rate of reaction to calculate and interpret the rate constant of a chemical reaction.
- ✓**3222.3.11** Calculate and interpret the reaction order based on the rate constant and concentration of reactants or products at various times during the reaction.
- ✓**3222.3.12** Draw an energy profile for catalyzed and uncatalyzed chemical reactions to identify the activation energy and illustrate the role of a catalyst in lowering the activation energy.
- ✓**3222.3.13** Write an equilibrium expression and calculate the equilibrium constant based on the concentration of reactants and products at equilibrium.
- ✓**3222.3.14** Interpret the magnitude of the equilibrium constant and use it to determine equilibrium concentrations and direction of a chemical reaction that has yet to reach equilibrium.
- ✓**3222.3.15** Use Le Chatelier's Principle to predict shifts in the direction of a chemical reaction in response to changes in temperature, pressure and concentration of reactants or products.
- ✓**3222.3.16** Calculate the percent ionization and pH of a solution given the identity, concentration, and acid/base dissociation constant of an acid or base.
- ✓**3222.3.17** Prepare a buffer of a specific pH and calculate the change in pH in response to addition of additional acid or base.
- ✓**3222.3.18** Perform a titration of a weak acid or weak base identifying the K_a or K_b and the pH at the equivalence point.
- ✓**3222.3.19** Characterize the strength of acids and bases by exploring their chemical structures.
- ✓**3222.3.20** Calculate the solubility product constant based on the concentration of soluble ions.
- ✓**3222.3.21** Interpret the magnitude of the solubility product constant in terms of the solubility of the substance.
- ✓**3222.3.22** Apply thermodynamic data to calculate the change in enthalpy, entropy, and Gibb's free energy of a chemical reaction.
- ✓**3222.3.23** Interpret the magnitude of the enthalpy and entropy change of a chemical reaction in terms of heat changes and order of the reaction components.
- ✓**3222.3.24** Interpret the magnitude of free energy change in terms of spontaneity of the chemical reaction.
- ✓**3222.3.25** Relate the magnitude of the free energy change to the equilibrium condition and reduction potential of the chemical reaction.